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MONITORING PROTOCOLS AND STRATEGIES FOR SELECTED INDICATORS IN THE TARIUM NIRYUTAIT MARINE PROTECTED AREA (MPA)

Shingle Point Camp.
Photo by Andrea Niemi, DFO.

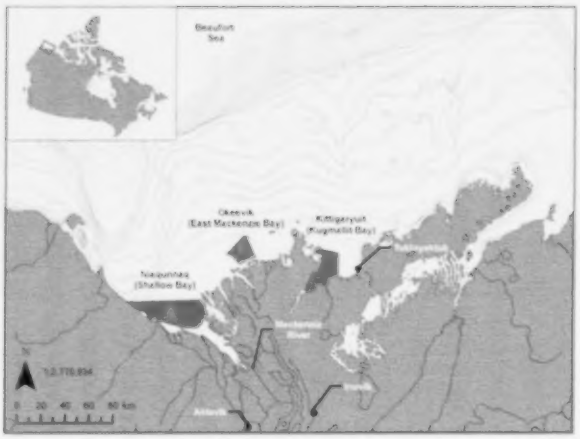

Figure 1. The Tarium Niryutait MPA sub-areas within the Mackenzie River Estuary in relation to the inner Beaufort Sea bathymetry.

Context

The Tarium Niryutait Marine Protected Area (TNMPA) was designated as the first Fisheries and Oceans Canada (DFO) Arctic MPA. The TNMPA is comprised of three sub-areas within the Mackenzie River Estuary within the Canadian Beaufort Sea (Figure 1). The conservation objective (CO) for this MPA is to conserve and protect Beluga Whales and other marine species (anadromous fishes, waterfowl and seabirds), their habitats and their supporting ecosystem.

DFO Oceans Program Division requested science advice on protocols and strategies for monitoring five selected indicators. This Science Advisory Report is from the February 9-10, 2012 peer review of monitoring protocols and strategies for the TNMPA priority indicators. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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SUMMARY

- Protocols and strategies for each indicator were based on previous or on-going research efforts in the Beaufort Sea to allow for comparison of results and efficient merging of datasets.
- *Species Lists (Indicator 1.1.1):* A draft species list (current to 2004) was developed for the TNMPA and surrounding area. Recent research in the area should be reviewed for additional species.
- *Surveys (Indicator 1.1.2):* No single survey method/design can effectively be used to collect data on the full variety of taxa in the TNMPA, therefore taxon-specific methods are required. The first step would be to compile existing spatial records and create distribution maps for some species and/or taxa.
- *Sighting Effort (Indicators 3.1.1 and 3.2.1):* Protocols for sampling Beluga distribution and abundance based on sighting effort are identical. The data collected can be analysed to provide information on both indicators. The continuation of standardized aerial surveys is the most effective method to monitor these indicators (including ice-edge reconnaissance aerial surveys). It is recommended that aerial survey monitoring should occur every 10 years for 2-3 consecutive years unless a significant stressor is recognized in or near the MPA boundaries.
- *Anthropogenic Noise (Indicator 6.1.1):* Passive Acoustic Monitoring (PAM) combined with monitoring Beluga distribution and abundance (Indicators 3.1.2 and 3.2.1) would be appropriate for monitoring this indicator. However, it is difficult to differentiate and measure anthropogenic noise in the nearshore Beaufort Sea where wind, waves and ice movement produce high levels of natural background noise.
- Evaluation of the efficacy of the indicators and the resulting indices should be an ongoing process. Protocols may need to be revised in the future.
- Recent monitoring data should be compared with data collected prior to a documented ecosystem shift (1990-1998). Further investigation is needed to determine baseline periods for individual indicators since this will affect the interpretation of the indicator.
- In any long-term monitoring plan for the TNMPA, it would be advantageous to include local community members from Aklavik, Inuvik and Tuktoyaktuk who use the MPA and live in the area year-round. This would allow for collaborative or participatory research/monitoring with local community members, would help offset the costs associated with a long-term monitoring plan and would provide a window of opportunity for the collection and inclusion of Traditional Ecological Knowledge (TEK).
- Appropriate databases need to be developed and maintained to store historical data for each indicator and to ensure accessibility for updating.
- Monitoring drivers and/or stressors that affect the indicators must occur simultaneously so that any changes can be associated with causal factors. At a minimum, monitoring of abiotic parameters is essential.
- Monitoring conducted solely within the bounds of the MPA will not necessarily be effective at detecting change. Linking monitoring activities within the MPA to research and monitoring in other areas would increase effectiveness, however when those programs come to an end new programs will need to be created to maintain the monitoring of those indicators.

INTRODUCTION

Under the Health of the Oceans Initiative, DFO Science sector provides advice to support the identification and development of MPAs. This includes the identification of indicators and monitoring protocols and strategies for inclusion in MPA monitoring plans and should be based on the conservation objectives set out for the MPA. The conservation objective developed for the Tarium Niryutait Marine Protected Area (TNMPA) is:

> *"to conserve and protect Beluga whales and other marine species (anadromous fish, waterfowl, and seabirds), their habitats and their supporting ecosystem."*

In 2010 regional science advisory meetings were held to identify indicators for monitoring the conservation objective for the TNMPA (DFO 2010). During these meetings, participants developed a hierarchical framework that contained six categories, each of which had two or more elements. A total of 82 indicators appropriate for monitoring the Beluga (*Delphinapterus leucas*) population and ecosystem health were identified. The highest priority indicators identified for the TNMPA were those related to the ongoing Hendrickson Island Beluga Study, a proposed community-based fish sampling program, the physical and chemical environment and anthropogenic noise (DFO 2010). Based in part on this advice, DFO Oceans Program selected five indicators and requested Science advice on the protocols and strategies for each of the selected indicators (Table 1).

Table 1. Categories, elements and priority indicators (chosen by DFO Oceans) that form a hierarchical framework for monitoring and assessing the TNMPA conservation objective. For detailed descriptions of indicators see Loseto et al. (2010).

Category	Element		Indicator	
1.0 ECOSYSTEM STRUCTURE	1.1 Biodiversity		1.1.1	Species lists
			1.1.5	Surveys
3.0 POPULATION STRUCTURE OF KEY SPECIES	Beluga	3.1 Distribution	3.1.1	Sighting effort
		3.2 Abundance	3.2.1	Sighting effort
6.0 NOISE AND OTHER PHYSICAL STRESSORS	6.1 Noise		6.1.1	Anthropogenic Noise

Description of the MPA

The TNMPA was officially designated as an MPA in August 2010. The MPA lies within the Inuvialuit Settlement Region (ISR) in the western Canadian Arctic on the Beaufort Shelf (Figure 1). The MPA consists of three separate and distinct sub-areas (Niaqunnaq, Okeevik and Kittigaryuit) within the nearshore region of the Mackenzie River Estuary, which together encompass approximately 1,800 km^2 (Figure 1). The region is greatly influenced by the Mackenzie River, the largest river system in Canada. The Mackenzie River watershed encompasses nearly 20% of the country's landmass, spilling large volumes of warm, fresh and sediment laden waters onto the shelf annually. This feature is one of the dominant environmental factors that influence the chemical and physical conditions in the TNMPA. The presence of ice (largely land-fast ice) in the MPA during the period from freeze-up to break-up also shapes the nature and function of this nearshore region, influencing both the chemical and physical conditions, and the biological structure and function.

The TNMPA supports a variety of species, most notably one of the largest summer aggregations of Beluga in Canada. Each summer, thousands of Beluga belonging to the Eastern Beaufort Sea population return to the shallow (<5 m) and warm (up to 20°C) Mackenzie River Estuary (including the TNMPA). The area also supports important summer feeding, migratory, and overwintering habitats for a number of anadromous and euryhaline fishes that rely on the inner, fresher, shallow-water portion of the Mackenzie River Estuary. A large abundance and high diversity of coastal waterfowl and seabirds also use the marine environment in the Mackenzie River Estuary (including the TNMPA), and a number of important adjacent terrestrial sites; Kendall Island Migratory Bird Sanctuary, Mackenzie Delta Important Bird Area, and two International Biological Programme Sites.

ASSESSMENT

A total of five indicators from three categories of the hierarchical framework were selected by the Oceans Program Division. Advice was requested regarding the protocols and strategies for monitoring each of these indicators. Of the five, three were identified by Science in 2010 as a high priority for monitoring (Indicators 3.1.1, 3.2.1 and 6.1.1; DFO 2010). Loseto et al. (2010) considered biodiversity indicators (Indicators 1.1.1 and 1.1.5) low priority since it may be more difficult to fully characterize biodiversity than it would be to observe changes in ecosystem structure using stable isotopes, fatty acids or contaminant tracers (Indicators 1.2.1, 1.2.2, 1.2.3).

The protocols and strategies for each indicator (Table 1) were evaluated (Higdon 2012) and formed the basis for discussion at the meeting. The goal was to comprehensively identify protocols and strategies that are currently being used in the TNMPA to monitor the selected indicators and to consider other applicable methods that may be used at other locations based on literature. Higdon (2012) reviewed current published information, including primary and secondary scientific and technical publications and consulted with researchers and experts.

With the exception of Indicator 1.1.1 (Species Lists), existing data for each indicator were not compiled nor evaluated for this meeting. Therefore, both the robustness of the indicators, and the protocols and strategies that were identified still require a full evaluation to ensure that:

- when a change is detected in an indicator it is significant and not a false-positive,
- the protocols (i.e., methods) for sampling are effective for measuring/detecting changes, and
- the appropriate temporal resolution can be determined for each indicator.

Stewart (2012) prepared a preliminary species list (Indicator 1.1.1) for the TNMPA based on published literature. This is the only indicator for which data have been compiled and published for MPA reporting purposes.

The following is a summary of protocols and strategies for monitoring the selected indicators. Detailed descriptions can be found in Higdon (2012).

Indicator 1.1.1: Species Lists

Species lists are a basic indicator of biodiversity/species richness and can provide some information about community structure. The value of a species list is that it creates a baseline of species that have been recorded as present in the TNMPA (Loseto et al. 2010). Initially, the list will document species richness for the region and highlight any knowledge gaps with respect to species occurrence.

There are a number of issues that can be encountered when using a species list as the sole indicator for assessing biodiversity and ecosystem structure in an MPA. It is a 'rough' tool and it can be difficult to detect and/or interpret a decrease or a 'negative' change in biodiversity based solely on a list. For example:

- Many areas of the Arctic are not fully explored and species lists may be incomplete as a result. New techniques (e.g., genomic techniques) for determining taxonomic diversity may become useful in the future for particular taxonomic groups (e.g., phytoplankton, microbes) (Indicator 1.1.3 in Loseto et al. 2010). Improvements in the precision of species identification and further research may create the illusion of new species and increased diversity when the species may have been present all along, or incorrectly identified.
- With the exception of the Arctic Coastal Ecosystem Studies (ACES) program, most of the past, current and planned research and monitoring in the TNMPA and surrounding areas have focused on understanding ecosystem function and structure or the management of harvested stocks. There are no dedicated biodiversity monitoring programs. The completeness of the species list may be dependent on sampling design and reporting, and the recording of effort, rather than as true changes to the species list.
- Changes in overall species composition (i.e., abundance of key species) will likely go unnoticed. An observed change in the species list will have been a response to change(s) that have already occurred in the MPA; they will not provide signals or warnings of imminent changes in biodiversity. Additional properly designed protocols and strategies that are specific to each taxon are required to detect signals of changes in biodiversity.
- A number of species that use the TNMPA are highly mobile and are only present in the MPA during certain times of the year. The presence or absence of these species in the MPA may not be a reflection of changes in the MPA, rather they could be the effect of changes that have occurred in other habitats (e.g., Beluga overwintering in the Bering Sea, Arctic Char spawning in freshwater systems).
- Species composition would not be temporally and/or spatially stable in the TNMPA due to the year-round influence of the Mackenzie River and the effect of ice (resulting in fluctuating abiotic conditions, ice scours, freeze-up, etc.). Temporal and spatial instability in sampling because of seasonal changes in accessibility to the area will also influence the completeness of the list.
- A taxonomic list of marine mammals will be relatively insensitive to environmental change.

It is unlikely that a single species list would be an effective monitoring tool however, lists may be appropriate for some taxa. For these, data could be used to calculate a number of biodiversity metrics (e.g., species richness, evenness) (Indicator 1.1.2, Loseto et al. 2010). It is recommended that a list of summer benthos (based on Stewart 2012) and fishes (based on Coad and Reist 2004) be compiled and updated for the TNMPA. In the short term, monitoring will likely be able to detect invasive species and range extensions for some species, based on literature and observations (Indicator 1.1.4; Loseto et al. 2010).

Protocols and Strategies

A draft species list (current to 2004) has been developed by Stewart (2012). Numerous research programs and data sources contributed to this species list, however recent research in the area should be reviewed for additional species (e.g., ACES).

The majority of work required to report on this indicator can be conducted regularly as a desk-based exercise through literature reviews, museum catalogues searches and interviews with active researchers. Data should be recorded as presence/absence information. Periodic synthesis and integration of new research, reports by local people and traditional ecological knowledge (TEK) are necessary to keep the list up to date and accurate. Since data collection for this indicator will be conducted on an opportunistic basis, it is recommended that a process to report notable/unusual observations and/or events should be established (e.g., community visits, a reporting form for submission) to supplement scientific studies/programs, however, the usefulness of this type of program would be limited and suspect unless observations are accompanied with voucher specimens.

It is recommended that managers consider storing the list in a comprehensive database for ease of input and access. A schedule for regular updates should also be implemented.

Indicator 1.1.5: Surveys

Surveys will be a critical component for monitoring ecosystem structure and biodiversity in the TNMPA. Surveys can be used to determine the distributions of species within an area and to identify habitat use (Loseto et al. 2010). No single survey method/design can effectively collect data on the full variety of taxa in the TNMPA, therefore taxon-specific methods will be required. In addition, it will not be possible to monitor every species of plant or animal that is known or expected to occur in the TNMPA, therefore it is necessary to identify key species within the MPA to focus on (e.g., Beluga, Broad Whitefish (*Coregonus nasus*), Arctic Cisco (*Coregonus autumnalis*) and Least Cisco (*Coregonus sardinella*); Loseto et al. 2010).

Protocols and Strategies

Survey designs should be similar to previous or on-going research efforts in the Beaufort Sea to allow comparison of results and efficient merging of datasets. The Circumpolar Biodiversity Monitoring Program (CBMP) and the ACES program provide important information that is useful for the development of a TNMPA biodiversity survey program. The program may be enhanced by including local people as citizen scientists.

There are existing spatial records for some species that occur in the TNMPA and the surrounding area (baseline data, spatial data and research protocols) that can be compiled to create distribution maps. This desk-based exercise would be a first step to identifying a baseline.

Techniques for collecting phytoplankton, zooplankton, benthos and oceanographic data should be based on the ACES program methods.

For benthos, physical sampling (e.g., grab or dredge) is recommended. Optical methods are highly limited due to the high turbidity in the Mackenzie River Estuary. It is important to survey the benthos at the end of the summer season, prior to freeze-up, to provide the most complete 'picture' of benthic communities possible. Seasonal differences will make it difficult to detect changes in benthic communities, therefore adequate spatial coverage and temporal sampling

needs to be incorporated into the survey design. New techniques (e.g., high resolution multi-beam mapping) may become useful in the future.

It is recommended that fish surveys within the MPA make use of non-lethal techniques, such as trap netting, in association with Beluga harvesting areas. Periodic use of lethal techniques (i.e., gill nets) in offshore habitats will be necessary to complement nearshore information from the trap nets.

Fish surveys outside the MPA would be a cost-effective way of monitoring populations and communities that are relevant to the MPA. Since fish are highly migratory, sampling needs to be conducted within a broader geographic area in order to understand species distributions and habitat use and to provide an index of change over a broader area that can be compared to local patterns. Some examples include long-term monitoring programs that have been conducted at 1) Phillips Bay, 2) Yukon North Slope, and 3) Tuktoyaktuk Harbour. Sampling protocols were established for each of these programs. Survey coverage could be increased by extending fish monitoring under the Integrated Fisheries Management Plan (IFMP) for Dolly Varden Char (*Salvelinus malma*) at Shingle Point and implementing the ecosystem approach in the coastal component of the Beaufort Sea Regional Environmental Assessment (BREA).

Seabirds and waterfowl fall outside DFO's area of management responsibility, therefore external expertise needs to be consulted to develop appropriate surveys for these species. However, Higdon (2012) does describe a number of survey methods that are available for marine birds.

Indicators 3.1.1 & 3.2.1: Beluga Distribution and Abundance Sighting Effort

The objective of using sighting effort as an indicator is to determine the density, timing of migration and habitat use of Beluga in the TNMPA sub-areas. All previous studies of Beluga distribution and abundance in the TNMPA have used identical sampling protocols. Information can be extracted from these studies to provide information on both indicators (Indicators 3.1.1 and 3.2.1).

Protocols and Strategies

The continuation of standardized aerial surveys is the most effective method to monitor these indicators. Survey protocols already exist and there is a long history of survey coverage (see Loseto et al. 2010). Turbidity in the nearshore environment can affect the sightability of Beluga and thus estimates of distribution and abundance. Management should be aware that the estimates produced are relative and not absolute. It is recommended that aerial survey monitoring occur for 2-3 consecutive years and then every 10 years unless a significant stressor is recognized in or near the MPA.

Collaborative monitoring beyond the MPA boundaries to determine shifts or changes in Beluga densities, timing of migration, and habitat use will also be an important component of a robust monitoring program. Monitoring in the wider area will provide information about the stability of the relative abundance of Beluga in the MPA. For this, both aerial surveys and satellite tagging are important tools for tracking and monitoring Beluga habitat use within and outside the MPA. Tracking will presumably extend beyond Canadian boundaries through international collaborations to document Beluga seasonal distributions (i.e., fall and winter).

In spring, as Belugas migrate into Canadian waters, they concentrate at the ice-edge while waiting to access the Mackenzie River Estuary. Accordingly, ice-edge reconnaissance aerial surveys are

useful for determining the timing of entry into and use of the MPA sub-areas.

There have been previous attempts to collect additional sighting effort data from boat-based surveys; however, these efforts proved unsuccessful because it is difficult to see animals below the surface (turbid waters), the animals are often counted twice and monitors cannot cover as broad an area as an aerial survey. Boat-based surveys would provide increased local participation to help document interesting/notable observations about behaviour (e.g., social interactions, unusual activities).

Another potential tool is a community-based monitoring (CBM) approach based on measuring catch and/or sightings per hour of hunting effort (CUPE) during Beluga harvesting activities. This would require training observers and recorders.

Passive Acoustic Monitoring (PAM) can detect cetaceans by the distinctive sounds they emit during communication, foraging and geolocation. This can be a cost-effective method for collecting long-term seasonal information about cetacean presence and relative abundance, however, there are a number of caveats associated with this method which may limit its usefulness (see Higdon 2012). This method is currently being tested in the TNMPA.

Indicator 6.1.1: Anthropogenic Noise

Anthropogenic noise affects Beluga behaviour. It is difficult to measure anthropogenic noise in the nearshore Beaufort Sea where wind, waves and ice movement produce naturally high levels of background noise. Accordingly, if this indicator is to be used, proxies (e.g., occurrence and location of sources) may be more easily monitored. Information on recorded vessel traffic in or near the TNMPA and other industrial activities could generate historical estimates of anthropogenic noise.

Past and present anthropogenic noise sources within or near the TNMPA include seismic surveys, vessel traffic (large and small), aircraft and site-specific activities. It is advantageous to develop a baseline for anthropogenic noise because the current level of activity is low but anticipated to increase in the near future.

Acoustic recordings were collected in the Beaufort Sea at two locations within two sub-areas of the TNMPA in July 2010. Recordings at Kittigaryuit were taken using a boat-based or shore-based hydrophone and a digital recorder; an autonomous recording device (AURAL) was deployed at Niaqunnaq. Future monitoring is planned in all three TNMPA sub-areas as part of the ACES monitoring program. Other programs that may provide baseline data are the Scientific Committee on Oceanic Research (SCOR) and the International Quiet Ocean Experiment (IQOE).

Protocols and Strategies

It is recommended that PAM combined with monitoring Beluga distribution and abundance (Indicators 3.1.2 and 3.2.1) would be appropriate for monitoring this indicator. Protocols for AURAL and handheld recording devices should:

- follow IQOE protocols for characterizing the soundscape;
- monitor a broadband of at least 10 kHz in order to capture the noise of small and large vessels, call frequencies and possibly part of the echolocation click band of Beluga; and
- combine sound measurement data with actual observations (i.e., measure noise while boats are in the area during the Beluga harvest).

Measurements in shallow areas represent a challenge for acoustic devices, which was evident from the AURAL data (deployed at 3 m depth) that were collected in Niaqunnaq during the July 2010 field season. The instrument was susceptible to waves, which tended to interfere with measurements. Also, in shallow waters, low frequency sounds cannot propagate over large distances, therefore this component of noise does not propagate into the MPA. Lastly, the deployment of AURALs requires special care to minimize interference.

At present, there are limited baseline data for anthropogenic noise (see Loseto et al. 2010). Studies of noise have been conducted near, but mostly outside the MPA for soundscape characteristics. A desk-based exercise of past and present trends (e.g., Brouwer et al. 1988) along with the monitoring of vessel traffic and development activities in or near the MPA would be beneficial.

Sources of Uncertainty

Since the selected indicators have not been formally evaluated for their usefulness and because a dedicated monitoring program was only recently developed for the TNMPA, there are a number of uncertainties associated with the identified protocols and strategies:

- Natural variability results in high uncertainty associated with all indicators. Protocols should be designed with this in mind and need to provide sufficient statistical power to detect significant changes.
- A number of key species are only present in the Mackenzie River Estuary for part of the year. When monitoring highly migratory species it is difficult to determine the cause of a detected change in the TNMPA when changes have occurred outside the MPA. Management will need to be aware of changes that occur outside the TNMPA in order to determine if the TNMPA has actually changed.
- Given that most of the data sources are from studies that were not designed following monitoring protocols (ACES is the exception), their use in this context requires explicit evaluation/interpretation to ensure their applicability and accuracy.
- Data collection and assessments are generally seasonally limited and therefore do not represent all of the processes occurring within the MPA.

CONCLUSIONS AND ADVICE

Ecosystem monitoring is an important tool that can be used to determine whether actions undertaken to conserve valued ecosystem components (VEC) are successful and to discover ecological trends within a given study area. Long-term monitoring is essential to determine MPA effectiveness and to improve management actions. Monitoring, along with research, will lead to a greater understanding of the mechanisms involved in the observed changes that are associated

with individual monitoring indicators (ACIA 2005). Understanding the current status of, and trends in, monitoring indicators in the Canadian Arctic is extremely important in light of climate change and increasing anthropogenic impacts to the environment. Given the limited data that is available and the array of changes that are expected to occur in the Arctic, it will likely be difficult to determine monitoring baselines. Regardless, the establishment of a baseline for the TNMPA against which data can be compared and evaluated is essential for any monitoring program. Based on existing literature, it appears that 1998 was a pivotal year during which abiotic conditions in the North changed (e.g., ACIA 2005, Furgal and Prowse 2008). It is therefore suggested that 1990 to 1998 be used as a baseline to which more recent collections are compared. However, further investigation is needed to determine if other baselines are more appropriate for individual indicators. The selection of a baseline period will affect the interpretation of the indicator.

It is important to consider that industrial activities and research studies have also changed over time. Therefore it is important to conduct a thorough evaluation of each indicator to its efficacy. Monitoring programs will need to be flexible, with the ability to discard uninformative indicators, adopt new indicators in response to emerging threats or to correct faulty methods.

The natural resources within the TNMPA and surrounding area are important for the health and well-being of the Inuvialuit people. Locals regularly travel to the Mackenzie River Estuary and potentially access one or more MPA sub-areas annually. Local people provide opportunities for observation and monitoring seasonally, while scientific ecological monitoring is often periodic and limited in duration. In any long-term monitoring plan for the TNMPA, it would be advantageous to include local community members from Aklavik, Inuvik and Tuktoyaktuk who use the MPA. Individuals would need to be trained to collect indicator data. This would allow collaborative or participatory research/monitoring with local community members who live in the area year round. It would also help offset the costs associated with long-term monitoring and would provide an opportunity to collect and include Traditional Ecological Knowledge (TEK). A number of the protocols and strategies identified can incorporate this type of monitoring approach.

Several of the identified field programs are components of current DFO Science research activities. Throughout the life span of these programs, data can be used for MPA monitoring, however, plans need to be developed for the continuation of monitoring at appropriate spatial and temporal scales long after these programs are completed. Appropriate databases will also need to be developed and maintained to store historical data for each indicator and to ensure accessibility for updating. The collation and assessment of all existing data for the selected parameters will enhance the development of a monitoring baseline. Additional data collection is necessary and urgent for some parameters.

Addition of indicators that exhibit greater sensitivity to local drivers and stressors will increase the accuracy and precision of monitoring outcomes. Monitoring of drivers and/or stressors that affect the indicators must occur simultaneously so that any changes can be associated with causal factors. Understanding the cause is important to provide advice about methods to adapt to change. At a minimum, monitoring of abiotic parameters is essential.

The development and tracking of indices that reflect the health or status of the TNMPA will provide a basis for adaptive management to meet the TNMPA conservation objectives. Combining indicators into an appropriate index will help broaden our understanding of the status of and change in the MPA over time. The development of an appropriate approach for monitoring conditions in the TNMPA should be a priority (e.g., Atlantic Zone Monitoring Program, Commission for Environmental Cooperation (2011)).

OTHER CONSIDERATIONS

- Monitoring conducted solely within the bounds of the MPA will not necessarily be effective at signaling change. Linking monitoring activities within the MPA to research and monitoring in other areas would increase effectiveness.
- Evaluations of the efficacy of the indicators and the resulting indices should be an ongoing process. Revised protocols may need to be developed and implemented in the future.
- No expertise for seabirds, shorebirds, waterfowl or polar bear (*Ursus maritimus*) was present at this meeting. Higdon (2012) provides information and references to other published works on marine birds, however, further information should be sought from relevant experts.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 9-10, 2012 regional advisory meeting on monitoring protocols and strategies for the Tarium Niryutait Marine Protected Area (MPA). Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press. 1042 p.

Brouwer, P., McDonald, J.W., Richardson, W.J., and Davis, R.A. 1988. Arctic industrial activities compilation: Volume 3; Canadian Beaufort Sea: seismic and sounding surveys, vessel movements, helicopter traffic, and site-specific activities 1980 to 1986. Can. Data Rep. Hydrogr. Ocean Sci. 32(3): 170 p.

Coad, B.W., and Reist, J.D. 2004. Annotated list of the Arctic marine fishes of Canada. Can. Manusc. Rep. Fish. Aquat. Sci. 2674: iv +112 p.

Commission for Environmental Cooperation. 2011. A Guide to Ecological Scorecards for Marine Protected Areas in North America. http://www.cec.org/Storage/98/9685_Marine_scorecard_en.pdf

DFO. 2010. Monitoring indicators for the Tarium Niryutait Marine Protected Area (TNMPA). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/059.

Furgal, C., and Prowse, T.D. 2008. Northern Canada. *In* From impacts to adaptation: Canada in a changing climate 2007. Edited by D.S. Lemmon, F.J. Warren, J. Lacroix and E. Bush. Government of Canada, Ottawa, ON. p. 57-118.

Higdon, J. 2012. Monitoring Protocols and Strategies for the Tarium Niryutait Marine Protected Area (MPA) Priority Indicators. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/113. iii + 30 p.

Loseto, L., Wazny, T., Cleator, H., Ayles, B., Cobb, D., Harwood, L., Michel, C., Nielsen, O., Paulic, J., Postma, L., Ramlal, P., Reist, J., Richard, P., Ross, P.S., Solomon, S., Walkusz, W., Weilgart, L., and Williams, B. 2010. Information in support of indicator selection for monitoring the Tarium Niryutait Marine Protected Area (TNMPA). DFO Can. Sci. Advis. Sec. Res. Doc. 2010/094. vi + 47 p.

Stewart, D.B. 2012. Species inhabiting the Tarium Niryutait Marine Protected Areas in the Canadian Beaufort Sea – Mackenzie Delta. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/091. ii + 82 p.

FOR MORE INFORMATION

Contact: Kevin Hedges
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, MB
R3T 2N6
Tel: (204) 983-3001
Fax: (204) 984-2403
E-Mail: Kevin.Hedges@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, MB
R3T 2N6

Telephone: (204) 983-5131
E-Mail:xcna-csa-cas@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs

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